PATENT SPECIFICATION 710,252

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COMPLETE SPECIFICATION.

Improvements in or relating to Power Plants Incorporating Gas Turbines.

We, D. NAPIER & SON LIMITED, a Company registered under the Laws of Great Britain, of 211 Acton Vale, London, W.3, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement :—

This invention relates to power plants incorporating gas turbines of the kind including means for delivering compressed air, with or without some products of combustion, to a number of combustion chambers in which the air or a proportion of it is burnt with fuel and from which the products of combustion, with any residual air, are discharged and act upon a turbine rotor.

The invention is applicable to power plants of the above general kind of the type in which the compressed air is delivered by an air compressor driven by the turbine or separately driven, or of the type in which a mixture of compressed air and combustion products constituted by the exhaust from a reciprocating internal combustion engine (hereinafter for brevity referred to simply as an internal combustion engine) operating with a substantial surplus of air is delivered to the combustion chambers, the exhaust gases having a proportion of residual air sufficient to enable them to be burnt with further fuel in the combustion chambers.

In a gas turbine of the type comprising an air compressor delivering air to a number of combustion chambers in which it is burnt with fuel and from which the products of combustion are discharged so as to impinge on the rotor of a turbine directly connected to the rotor of the compressor by a main shaft the combustion chambers being arranged in a circle about the axis of the main shaft, it has been proposed to support the combustion chamber in a carrier rotatable about the axis of the main shaft and so to form and arrange air inlet ports leading from the compressor, and discharge ports leading to the nozzles or the equivalent through which the gases are directed on to the turbine rotor that each combustion chamber during its rotational movement first comes into communication with an air inlet port while it is also in communication with a discharge port so as to be charged with air, is then cut off from both air inlet and discharge ports for a period during which the air is partially or wholly burnt with fuel and then comes into communication with a discharge port before coming again into communication with the next air inlet port for recharging and so on, so that combustion takes place in the combustion chambers partly or completely under constant volume conditions instead of under constant pressure conditions as is the case where the combustion chambers are stationary and combustion therein is a continuous process.

An object of the present invention is to provide an improved form of power unit of the kind referred to which, while having combustion chambers in which combustion takes place partly or completely at constant volume, will reduce or eliminate some of the practical difficulties associated with the previous proposal referred to above.

A power plant according to the invention comprises means for delivering compressed air with or without a proportion of products of combustion to a plurality of combustion chambers in which the air is wholly or partly

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burnt with fuel and from which the products of combustion with any residual air are discharged so as to act on the turbine rotor, in which the combustion chambers are arranged in two or more groups each consisting of two or more combustion chambers, and each group of combustion chambers is mounted to rotate bodily about an axis equidistant from the axes of the combustion chambers constituting the group so as to bring air inlet ports at the inlet ends of the combustion chambers in the group in turn into communication with a fixed air delivery port and gas outlet ports at the outlet ends of the combustion chambers in the group in turn into communication with a fixed gas discharge port so that each of the combustion chambers is brought into communication with its associated air delivery and gas discharge ports for the appropriate periods between periods of constant volume combustion during which it is cut off from both ports.

It will generally be found convenient, and where the source of compressed air is an axial flow compressor it may be important, to arrange the timing of the charging periods of the combustion chambers in each group so as to provide for an overlap between the end of the charging period of each combustion chamber in the group and the beginning of the charging period of the next combustion chamber in the group. Moreover the arrangement is preferably such as to maintain the rate of flow of air into each group as a whole as nearly constant as possible and thus reduce or eliminate the effects which a pulsating delivery might have upon the operation of the compressor.

In a power plant incorporating the invention either the whole of the fuel which is to be burnt with air in each combustion chamber may be injected direct into the combustion chamber, or a proportion or the whole of the fuel may be injected into the air as or before it enters the combustion chamber. In the case where the whole of the fuel is injected into the combustion chamber it may be ignited spontaneously by the heat of the air or by ignition means in the form of an ignition plug or the like. Where on the other hand the whole of the fuel is delivered into the air before it enters the combustion chamber ignition may be caused by an ignition plug or the like while where a proportion only of the total fuel injected is delivered into the air before it enters the combustion chamber ignition may be either by an ignition plug or spontaneously upon injection of the additional quantity of fuel direct into the combustion chamber.

The invention may be applied to power plants of a considerable variety of types embodying gas turbines but one form of the invention as applied to a simple power plant of the kind comprising an air compressor delivering air to combustion chambers the products of combustion from which act on a turbine driving the compressor, is illustrated somewhat diagrammatically by way of example in the accompanying drawings, in which.

Figure 1 is a side elevation of the essential parts of the complete power plant partly in section and partly broken away,

Figure 2 is a cross-section on an enlarged scale on the line II—II of Figure 1 looking in the direction of the arrows,

Figure 3 is a similar view to Figure 2 on the line III—III of Figure 1,

Figure 4 is a sectional side elevation on an enlarged scale of the assembly comprising one group of combustion chambers.

Figure 5 is a diagrammatic sectional end elevation showing the general arrangement of gearing by which rotation is imparted to the various groups of combustion chambers,

Figure 6 illustrates diagrammatically a modification according to the invention, and

Figure 7 is a cross-section on the line VII—VII of Figure 6.

In the construction illustrated in Figures 1 to 5 the power plant comprises an axial flow air compressor A arranged to draw air from an annular air inlet A^1 and deliver it to a series of air delivery passages, five in number, indicated at A^2, terminating in air delivery ports A^3, of the contour shown in Figure 2, in a plate B of circular form.

The rotor A^4 of the air compressor A is mounted on a main shaft C supported in bearings C^1, C^2 and C^3 respectively in the plate B, in a plate D forming part of the structure of a turbine E, and in a plate A^5 forming part of the structure of the compressor. The rotor E^1 of the turbine E is also mounted on the shaft C while its nozzle ring E^2 or the equivalent is arranged to be fed with working fluid through a series of passages F, hereinafter called the gas passages, which are five in number and lead to the nozzle ring respectively from gas discharge ports F^1 in a plate G which is of circular form similar to the plate B, the ports F^1 being of the contour shown in Figure 3.

Each port A^1 is associated with one of the ports F^1 to which it lies most nearly opposite.

As will be seen from Figures 1 and 4 the plates B and G are separated by a substantial space and in this space lie and rotate five groups of combustion chambers which receive air from the compressor A respectively by way of the air delivery ports A^3 and from which the products of combustion are discharged through the gas discharge ports F^1 and passages F to the turbine nozzle ring, each group receiving air from one of the air delivery ports A^3 and

discharging its combustion products through the associated gas discharge port F^1.

Each group of combustion chambers is included in an assembly comprising a pair of spaced circular end plates H, H^1 supported in a manner hereinafter described at opposite ends of a shaft J supported in bearings in the plates B and G, the axis of which shaft is displaced from the ports A^3 and F^1 with which the combustion chamber group is associated by approximately equal distances. Each plate H has three air inlet ports H^2 formed therein and of the contour and disposition relatively to the axis of the shaft J indicated in Figure 2, while each plate H^1 has three outlet ports H^3 formed therein and of the contour and disposition indicated in Figure 3. The air inlet ports H^2 lead into tubular members H^4 formed on the plate H while the outlet ports H^3 open out of similar tubular members H^5 formed on the plate H^1, each pair of tubular members H^4 and H^5 constituting the ends of a combustion chamber the body part of which is constituted by a tubular shell H^6 extending between and supported at its ends by the tubular members.

Mechanism, hereinafter described, is provided for driving each of the shafts J so as to cause rotation of the group of combustion chambers associated therewith and in order to maintain a fluid seal between each of the plates H and the plate B and between each of the plates H^1 and the plate G, while preventing excessive frictional drag and allowing for thermal expansion, each of the plates H and H^1 is mounted on a quick-pitch screw-thread J^1 on the shaft J and is pressed towards its associated plate B or G by means of a helical spring J^2, the direction of rotation of the shaft J being such that the frictional drag imposed on each of the plates H and H^1 by reason of its contact with its associated plate B or G causes the quick-pitch screw-threads J^1 to tend to draw the plates H and H^1 out of contact with their associated plates B and B^1. It will thus be seen that under all conditions a substantially constant contact pressure between the engaging faces of the plates tends to be maintained since any increase in contact pressure increases the frictional drag and thus increases the tendency for the quick-pitch screwthread to draw the plates out of contact and vice versa. In a modification instead of the screwthread J^1, helical splines may be engaged to connect each of the plates H, H^1 to the shaft J.

The rotary transmission mechanism for rotating the shafts J comprises a main lay-shaft K driven by bevel gearing K^1 from a shaft K^2 which is itself driven by bevel gearing K^3 from the main shaft C, the end of the shaft K remote from the bevel gearing K^1 being supported in bearings in a gear casing L on the plate B and carrying a gear wheel K^4 from which the various shafts J are driven through intermediate transmission gearing the layout of which is shown diagrammatically in Figure 5. As will be seen this gearing is arranged so that gears J^3 on three of the five shafts J are driven by a series of intermeshing gear wheels from one circumferential point on the gear wheel K^4 while similar gears J^3 on the remaining two shafts J are driven by another series of intermeshing gear wheels from another circumferential point on the gear wheel K^4.

The manner in which fuel is supplied to and ignited in each combustion chamber may vary but in the example shown it is assumed for convenience that the fuel is delivered with the air into each combustion chamber and ignited therein by an igniting plug indicated at M supplied with a spark impulse at appropriate timed intervals. Instead of being mounted in the combustion chambers as shown, the ignition plug may be mounted in the stationary plate B at a point which is periodically exposed by the ports H^2 of the combustion chambers.

The arrangement and disposition of the air inlet ports H^2 in relation to the air delivery ports A^3 and of the outlet ports H^3 in relation to the gas discharge ports F^1 is such that during rotation of each combustion chamber group the outlet port of each combustion chamber may be regarded as first coming into communication with its associated gas discharge port while the air inlet port at the inlet end of the combustion chamber is still closed. Then at a predetermined point in the open period of the outlet port, the air inlet port comes into communication with the air delivery port A^3. Then the outlet port is closed somewhat before the air inlet port closes, whereupon the ignition plug is energised to cause combustion in the combustion chamber and the outlet port opens again. Thus, considering each combustion chamber, the cycle of operations comprises a scavenging period while the ports H^2 and H^3 are open, a charging period while the port H^2 remains open and the port H^3 is closed, a constant volume combustion period while both ports are closed and combustion takes place, and an exhaust period followed immediately by the scavenging period when both ports are again open, and so on.

For convenience of illustration Figures 2 and 3 respectively show the ports H^2 in the position in which one of them in each group exactly coincides with its associated port A^3 and show the ports H^3 in the position in which one of them in each group exactly coincides with its associated port F^1. It will be understood, however, from the above description that each port H^3 will be angularly displaced to an appropriate degree about the axis of its shaft J with respect to its

associated port H^2 as by making the members H^4 and H^5 of appropriate form. Alternatively each port H^3 could lie approximately in line with its associated port H^2 and each port F^1 could be appropriately angularly displaced about the axis of its adjacent shaft J with respect to its associated port A^2.

Moreover the form of the ports H^2 and A^2 is such that in each combustion chamber group the periods of opening of the three ports H^2 overlap in such a manner as to provide a substantially constant port area for the entry of air to the combustion chambers of the group as a whole whereby the bad effect on the compressor which a pulsating delivery would have tends to be eliminated.

In the modification shown in Figures 6 and 7 the general arrangement would be the same as that shown in Figures 1 to 5 but the form of the turbine and the means for delivering the working gases thereto are different from Figures 1 to 5. In this modified construction the turbine comprises a blade ring N constituting an "impulse" stage and a pair of blade rings N^1 constituting a normal expansion stage, the stage N being provided with a nozzle ring N^2 and the stage N^1 with a nozzle ring N^3. Moreover each of the gas discharge ports F^1 in this construction is divided as shown in Figure 7 into two sections 0, 0^1 of which the section 0 first comes into communication with each of the ports H^3 during each cycle so as to receive the first burst of gas from each combustion chamber, while the section 0^1 then comes into communication with the port A^3 during the normal expansion and scavenging periods. The sections 0 lead direct to the nozzle ring N^2 while the sections 0^1 lead through passages 0^2 direct to the nozzle ring N^3 to which also flow the gases from the stage N.

Thus, with this arrangement, the blade ring N and its associated nozzle ring N^2 receive the first impulse of the escaping gases and are designed as an impulse type turbine while the blade rings N^1 and their associated nozzle ring N^3 and any intermediate stator blade rings are designed as an expansion turbine thus tending to use the energy of the gases from the combustion chambers to best advantage.

Although the invention has been particularly described above with reference to a construction in which the fuel and air are mixed before they enter the combustion chambers and are ignited by ignition plugs, it is to be understood that the fuel may be injected into each combustion chamber and ignited either by an ignition plug or by the heat of the compressed air, or part of the fuel may be supplied with the air into each combustion chamber and the remainder injected direct into such chamber, in which case the final injection may cause automatic compression-ignition.

Where the phrase "air is wholly or partly burnt with fuel" is used throughout the Specification and claims it should be understood that fuel is supplied to the air under suitable conditions of temperature and pressure in such amount as to cause the oxygen to be partly or wholly consumed by chemical reaction.

What we claim is:—

1. A power plant comprising means for delivering compressed air with or without a proportion of products of combustion to a plurality of combustion chambers in which the air is partly or wholly burnt with fuel and from which the products of combustion with any residual air are discharged so as to act on a turbine rotor in which the combustion chambers are arranged in two or more groups each consisting of two or more combustion chambers and each group of combustion chambers is mounted to rotate bodily about an axis equidistant from the axes of the combustion chambers constituting the group and so as to bring air inlet ports at the inlet ends of the combustion chambers in the group in turn into communication with a fixed air delivery port and gas outlet ports at the outlet ends of the combustion chambers in the group in turn into communication with a fixed gas discharge port so that each of the combustion chambers is brought into communication with its associated air delivery and gas discharge ports for the appropriate periods between periods of constant volume combustion during which it is cut off from both ports.

2. A power plant as claimed in Claim 1, in which the period during which each combustion chamber in a group communicates with the turbine overlaps substantially the period during which such combustion chamber is in communication with the compressor.

3. A power plant as claimed in Claim 1 or Claim 2, in which each group of combustion chambers comprises at least three combustion chambers and the arrangement is such that the open area of the air delivery port associated with the air inlet ports in each group remains approximately constant through the rotation of the group so as to reduce or eliminate pulsation effects on the compressor.

4. A power plant as claimed in Claim 1, in which each group of combustion chambers extends between end plates which rotate with the group and have inlet and outlet ports therein communicating respectively with the ends of the combustion chambers, and in which the outer faces of the end plates make contact with the adjacent faces

of stationary end members having air delivery and gas discharge ports therein communicating respectively with the compressor and turbine, one or more springs tending always to maintain the adjacent faces of the end plates and the stationary members in engagement, and means whereby the frictional drag between these engaging faces tends to separate them.

5. A power plant as claimed in Claim 4, in which the end plates between which the combustion chambers of each group extend are mounted on a driving shaft to which they are connected by helical splines, quick-pitch screwthreads or equivalent means which cause relative rotation between the shaft and the plates to cause relative axial movement of these parts, and spring means tending always to move the plates away from one another on the shaft, the direction of rotation of the shaft being such that frictional drag on the end plates will act through the helical splines or the equivalent to tend to move the plates towards one another.

6. A power plant as claimed in Claim 1, in which there are three combustion chambers in each group.

7. A power plant as claimed in any one of the preceding claims, in which the turbine includes an impulse stage and one or more normal expansion stages and the arrangement is such that after each combustion the gas first released from each combustion chamber is delivered to the impulse stage from which it passes to the normal expansion stage or stages whereas the gas subsequently discharged from each combustion chamber passes direct to the normal expansion stage or stages.

8. A power plant constructed substantially as described and diagrammatically illustrated in Figures 1 to 5 of the accompanying drawings or as described with reference to Figures 6 and 7 of the accompanying drawings.

KILBURN & STRODE,
Agents for the Applicants.

PROVISIONAL SPECIFICATION.

Improvements in or relating to Power Plants Incorporating Gas Turbines.

We, D. Napier & Son Limited, a Company registered under the Laws of Great Britain, of 211 Acton Vale, London, W.3, do hereby declare this invention to be described in the following manner :—

This invention relates to power plants incorporating gas turbines of the kind including means for delivering compressed air, with or without some products of combustion, to a number of combustion chambers in which the air or a proportion of it is burnt with fuel and from which the products of combustion, with any residual air, are discharged and act upon a turbine rotor.

The invention is applicable to power plants of the above general kind of the type in which the compressed air is delivered by an air compressor driven by the turbine or separately driven, or of the type in which a mixture of compressed air and combustion products constituted by the exhaust from a reciprocating internal combustion engine (hereinafter for brevity referred to simply as an internal combustion engine) operating with a substantial surplus of air is delivered to the combustion chambers, the exhaust gases having a proportion of residual air sufficient to enable them to be burnt with further fuel in the combustion chambers.

In a gas turbine of the usual type comprising an air compressor delivering air to a number of combustion chambers in which it is burnt with fuel and from which the products of combustion are discharged so as to impinge on the rotor of a turbine directly connected to the rotor of the compressor by a main shaft the combustion chambers being arranged in the usual manner in a circle about the axis of the main shaft, it has been proposed to support the combustion chamber in a carrier rotatable about the axis of the main shaft and so to form and arrange air inlet ports leading from the compressor, and discharge ports leading ot the nozzles or the equivalent through which the gases are directed on to the turbine rotor that each combustion chamber during its rotational movement first comes into communication with an air inlet port while it is also in communication with a discharge port so as to be charged with air, is then cut off from both air inlet and discharge ports for a period during which the air is partially or wholly burnt with fuel and then comes into communication with a discharge port before coming again into communication with the next air inlet port for recharging and so on, so that combustion takes place in the combustion chambers partly or completely under constant volume conditions instead of under constant pressure conditions as is the case where the combustion chambers are stationary and combustion therein is a continuous process.

An object of the present invention is to

provide an improved form of power unit of the general kind referred to which, while having combustion chambers in which combustion takes place partly or completely at constant volume, will reduce or eliminate some of the practical difficulties associated with the previous proposal referred to above.

A power plant of the kind referred to according to the present invention, includes combustion chambers arranged in two or more groups each consisting of one or more combustion chambers, a fixed inlet port associated with each group leading from the source of compressed air and a fixed discharge port associated with each group leading to the turbine and means whereby the combustion chamber, or each of the combustion chambers constituting a group is first brought into communication with its associated inlet port while in communication with its associated discharge port so as to be charged, is then cut off from both its associated ports for a period during which the air therein is partially or wholly burnt with fuel and is then brought into communication with its associated discharge port so that the products of combustion begin to be delivered to the turbine, before being brought again into communication with its inlet port for recharging, and so on.

Where each combustion chamber group consists of one chamber only suitable valve or transfer device would be associated with the two ends of each combustion chamber to connect them to their associated inlet and discharge ports at the appropriate periods. In one example of such an arrangement each transfer device might rotate about the axis of a port through which one end of the transfer device communicates continuously with the combustion chamber, the combustion chamber being either stationary or rotating with the transfer devices, while the other end of the transfer device has a port arranged eccentrically with respect to its axis of rotation so as to come into communication with an inlet or discharge port in a fixed part for the required periods.

Where on the other hand, as will generally be preferable, each combustion chamber group comprises two or more combustion chambers, then in one arrangement each such group rotates bodily about an axis equidistant from the axes of the combustion chambers constituting it so as to bring ports at the inlet ends of the combustion chambers in the group in turn into communication with a stationary inlet port and ports at the discharge ends of the combustion chambers in the group in turn into communication with a stationary discharge port so that each of the combustion chambers is brought into communication with its associated inlet and discharge ports for the appropriate periods between the periods of constant volume combustion when it is cut off from both ports.

Alternatively, rotary transfer devices or members may be provided at the opposite ends of each group of combustion chambers, the transfer member at the inlet end having a passage therein the inlet end of which is in continuous communication with the source of compressed air while its outlet end is eccentric with respect to its axis of rotation and comes in turn into communication with the inlet ends of the combustion chambers in the group, while the transfer member at the discharge end of each group has a passage therein the discharge end of which is in continuous communication with the turbine while its inlet end has a port which is eccentric with respect to its axis of rotation and comes in turn into communication with the discharge ends of the combustion chambers in the group. In such an arrangement the two transfer members would be driven in synchronism and the formation of the various ports would be such as to provide for the appropriate timing of the charging, combustion, and discharging periods.

The number of combustion chambers in each group in either of the arrangements described above having two or more combustion chambers in each group may vary but in a preferred arrangement there would be three combustion chambers in each group since three combustion chambers of the usual cylindrical form can be arranged in a compact group about an axis.

In any case whether each group comprises two or more combustion chambers which rotate about an axis, this axis conveniently lies at a smaller radial distance from the axis of the turbine rotor than does the fixed discharge port so as to maintain the overall dimensions of the assembly wall.

It will generally be found convenient, and, where the source of compressed air is an axial flow compressor may be important, to arrange the timing of the charging periods of the combustion chambers in each group so as to provide for an overlap between the end of the charging period of each combustion chamber and the beginning of the charging period of the next combustion chamber to be charged. Moreover, the arrangement would preferably be such as to maintain the rate of flow of air into the group as a whole as nearly constant as possible and thus reduce or eliminate the effects which a pulsating delivery might have upon the operation of the compressor.

In a power plant incorporating the invention either the whole of the fuel which is to be burnt with air in each combustion chamber may be injected direct into the combustion chamber, or a proportion or the whole of the fuel may be injected into the air as or before it enters the combustion chamber.

In the case where the whole of the fuel is injected into the combustion chamber it may be ignited spontaneously by the heat of the air or by ignition means in the form of an ignition plug or the like. Where on the other hand the whole of the fuel is delivered into the air before it enters the combustion chamber ignition may be caused by an ignition plug or the like while where a proportion only of the total fuel injected is delivered into the air before it enters the combustion chamber ignition may be either by an ignition plug or spontaneously upon injection of the additional quantity of fuel direct into the combustion chamber.

The invention may be applied to power plants in which the turbine drives an air compressor by which air is delivered to the combustion chambers, to power plants in which a separate engine is used to drive an air compressor delivering air to the combustion chamber, or to power plants in which the compressed air mixed with products of combustion is derived from the exhaust of an internal combustion engine in which fuel is burnt with surplus air and which either serves only as a source of compressed air for the combustion chambers or also delivers mechanical power from its crank shaft. Again, the invention is applicable to power plants in which the groups of combustion chambers are disposed between two turbines or two stages of a turbine the first of which is fed with products of combustion and air from the exhaust of an internal combustion engine as above described or from combustion chambers supplied with excess air from an air compressor, while the second receives its working fluid from the groups of combustion chambers according to the invention in which a further proportion of the air has been burnt.

Further, in any case the turbine which receives products of combustion from the groups of combustion chambers according to the present invention may either serve simply to drive an air compressor supplying air to the groups of combustion chambers, or to an internal combustion engine from which air mixed with products of combustion flows to the groups of combustion chambers or may serve in addition or alternatively to drive other apparatus.

Thus when the invention is applied to a power plant for aircraft propulsion the turbine may simply drive a compressor supplying air to the combustion chambers and the exhaust from the turbine may pass to a propulsion nozzle, or in addition the turbine may drive a propeller, while when the invention is applied to a power plant including an internal combustion engine as above described the turbine might drive a supercharging compressor alone or also drive a propeller.

When, as in one preferred form of the invention the turbine drives a compressor from which the air is delivered to the combustion chambers and either also drives a propeller or not, the exhaust gases from the turbine passing to a propulsion nozzle, the invention may be regarded as an improvement in power plants of the kind in which hitherto the working fluid for the turbine has been derived from the exhaust gases of an internal combustion engine serving in effect as a gas producer, since the combustion in the combustion chambers of power plants incorporating the present invention, taking place under conditions of approximately constant volume, may be likened to the combustion in the chambers of a piston type internal combustion engine.

Further, the turbine to which the products of combustion from the combustion chambers flow in power plants according to the invention may either have a first stage suited to the high pressure at which the first part of each discharge from each combustion chamber takes place as well as to the later lower pressure part of each discharge, or alternatively means may be provided for causing the first high pressure part of each discharge to act on a special ring of turbine blades or pass through two or more special stages of the turbine which are by-passed by the later lower pressure parts of each discharge. This can be achieved by suitable formation and arrangement of the discharge ports so that each discharge port is subdivided and the part leading to the special high pressure section of the turbine opens somewhat before the other part which leads to the lower pressure section of the turbine.

It is to be understood that where a turbine is referred to in the present Specification this term includes both single stage and multi-stage turbines and two or more turbines having separate rotors either geared together or not and either arranged in parallel or in series as regards the passage of gas therethrough.

Again, although particular reference has been made to axial flow air compressors, the invention is applicable to power units employing centrifugal air compressors, or a combination of axial flow and centrifugal air compressors or air compressor stages.

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Agents for the Applicants.

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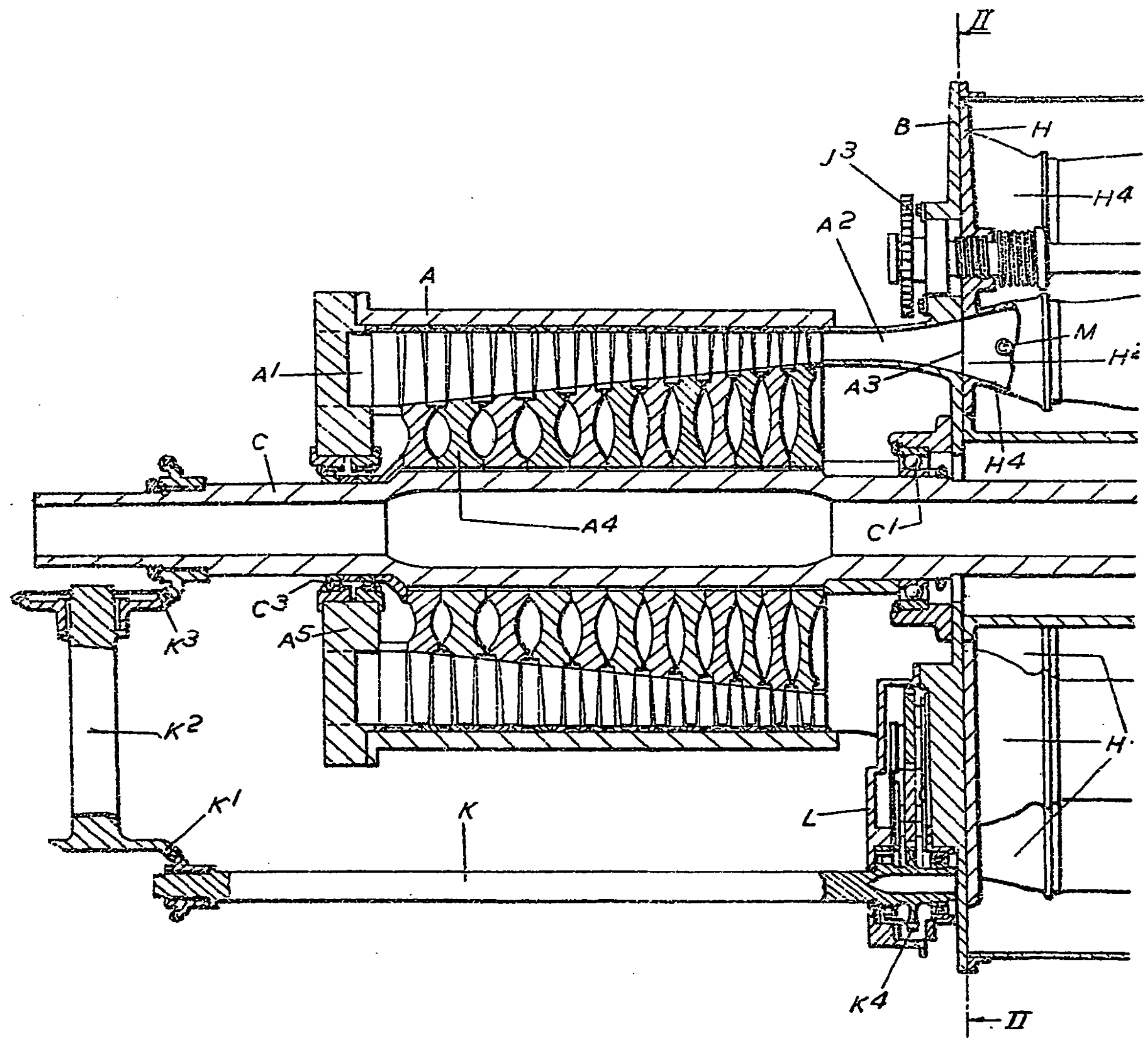
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SHEET 1

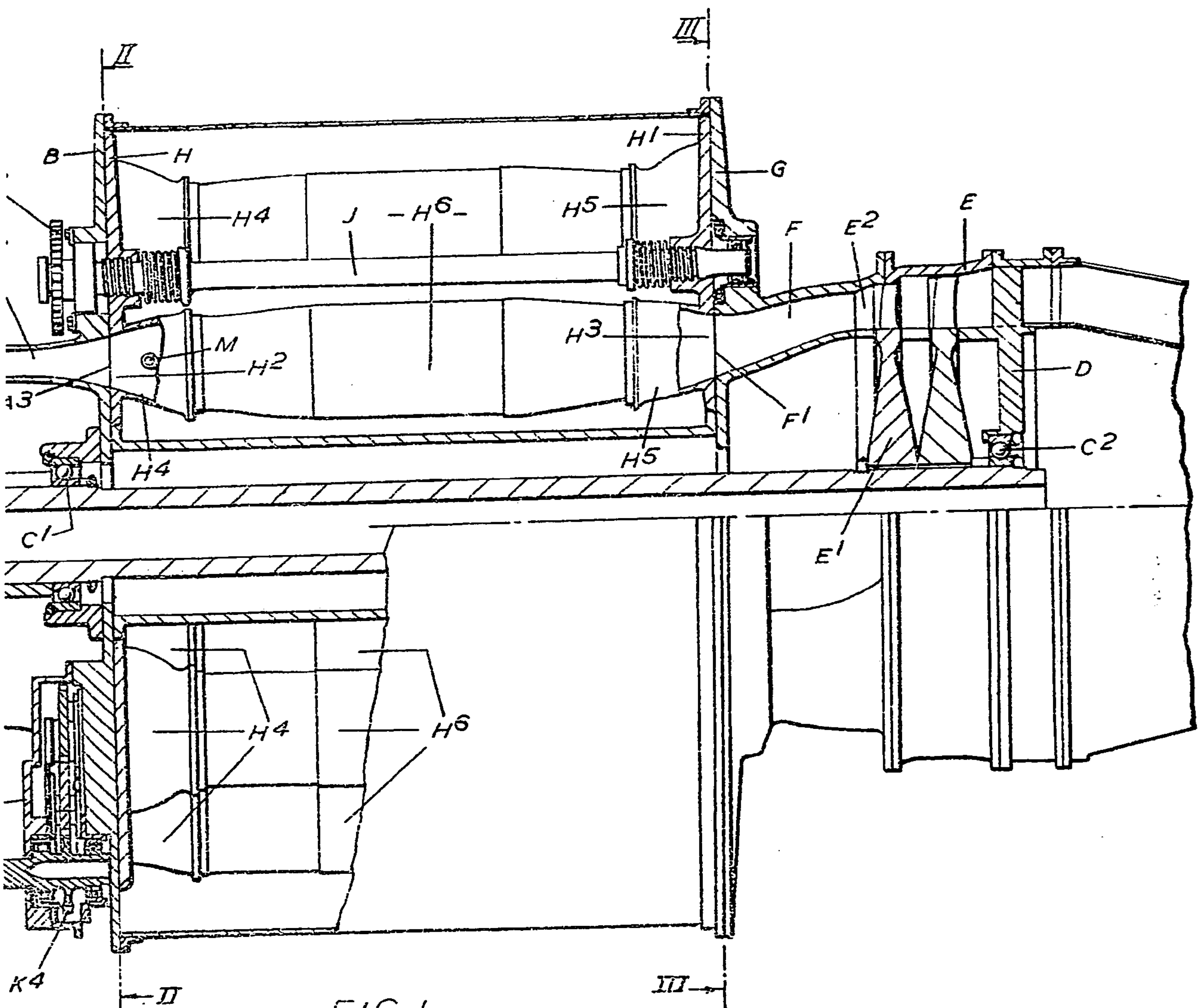

FIG.1.

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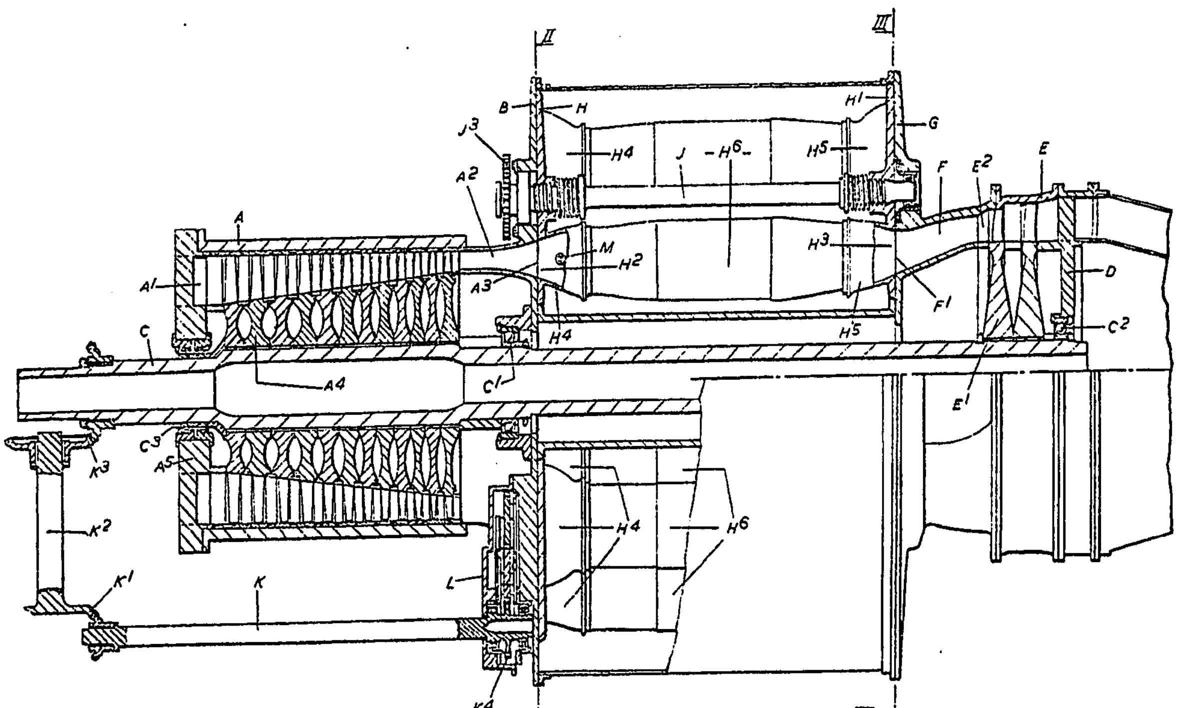


FIG. 1.

FIG.2.

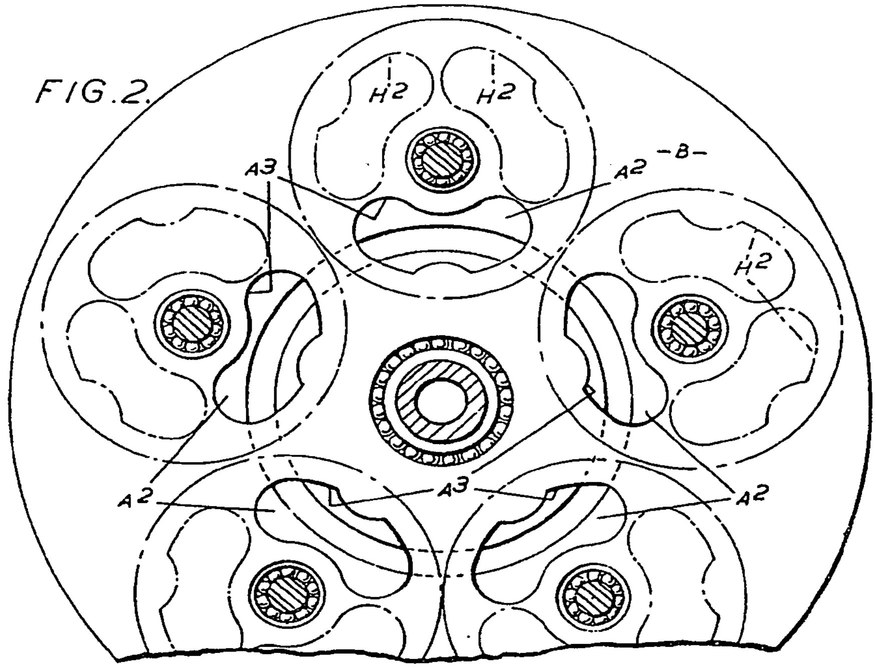
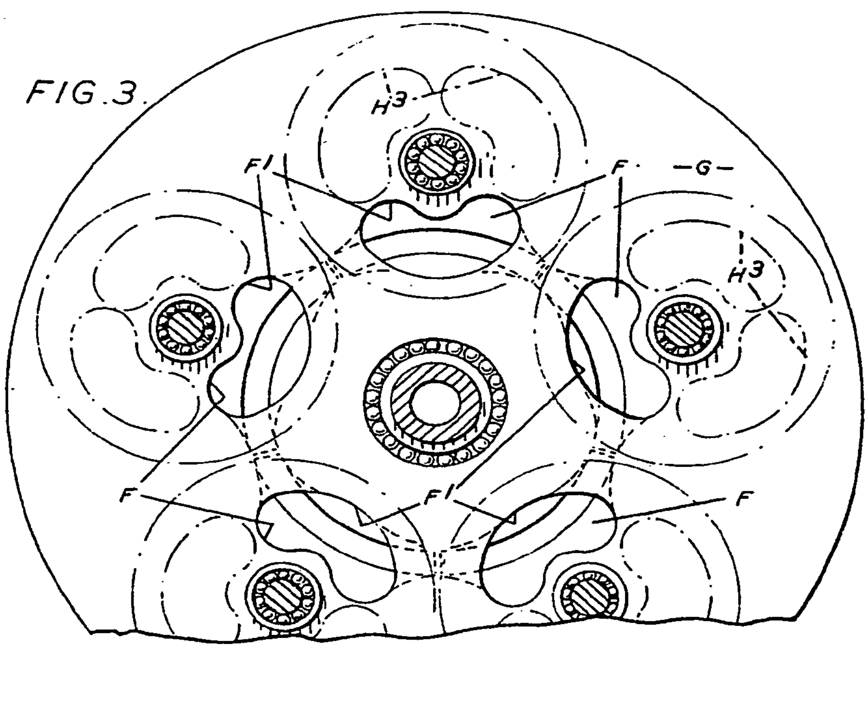


FIG.3.



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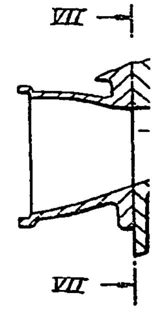

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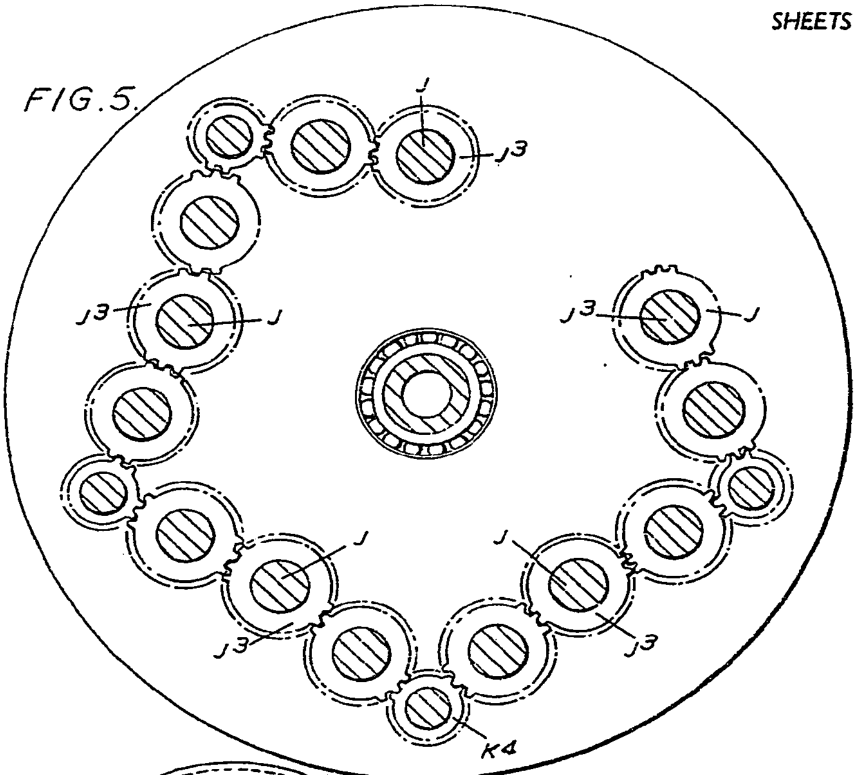
SHEETS 2 & 4

FIG.5.



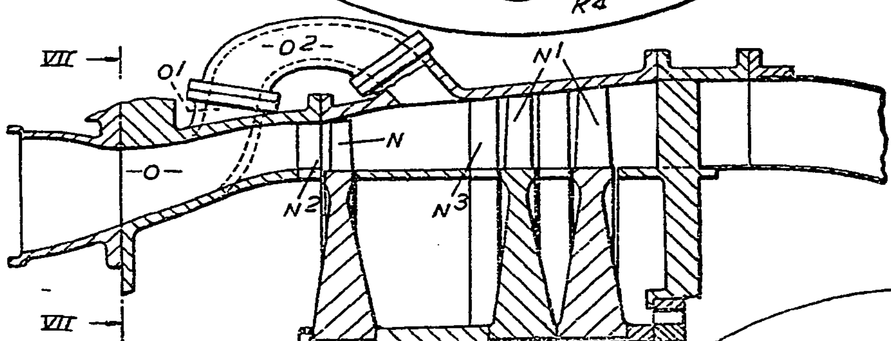
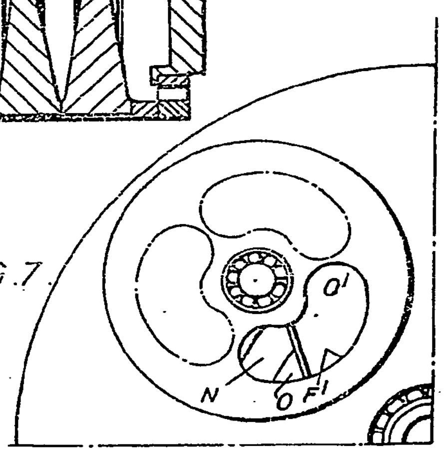


FIG.6.

FIG.7.



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SHEETS 2 & 4

FIG.2.

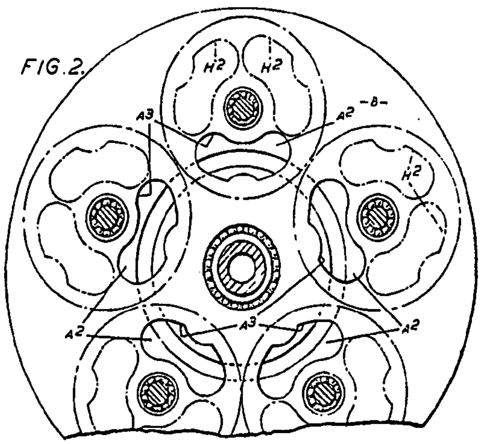


FIG.3.

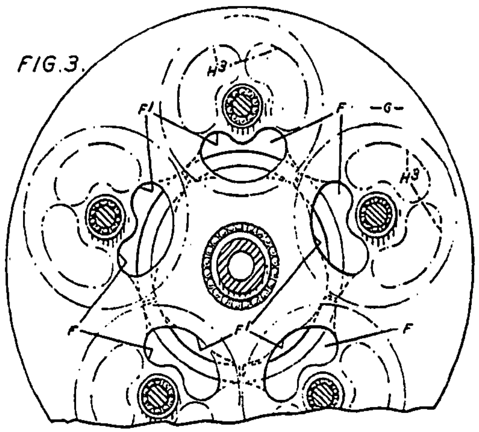
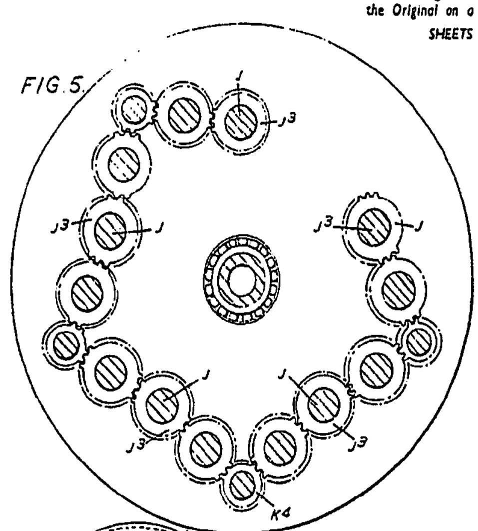


FIG.5.



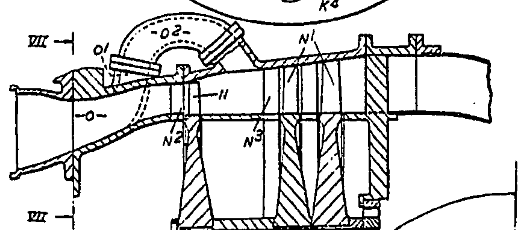


FIG.6

FIG.7

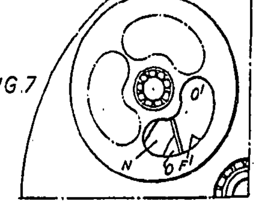
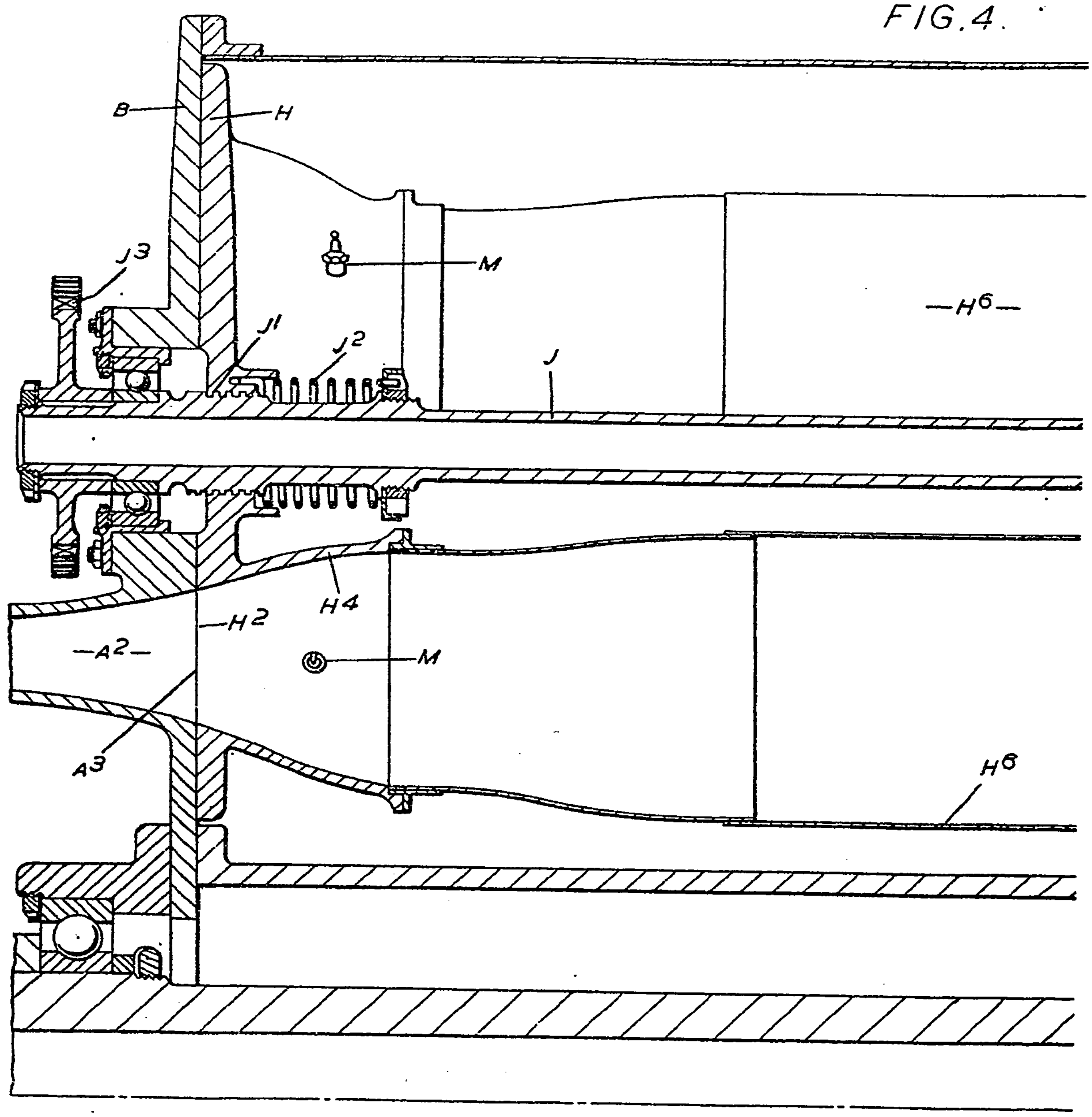


FIG.4.



710,252 COMPLETE SPECIFICATION
4 SHEETS

This drawing is a reproduction of the Original on a reduced scale.

SHEET 3

FIG. 4.

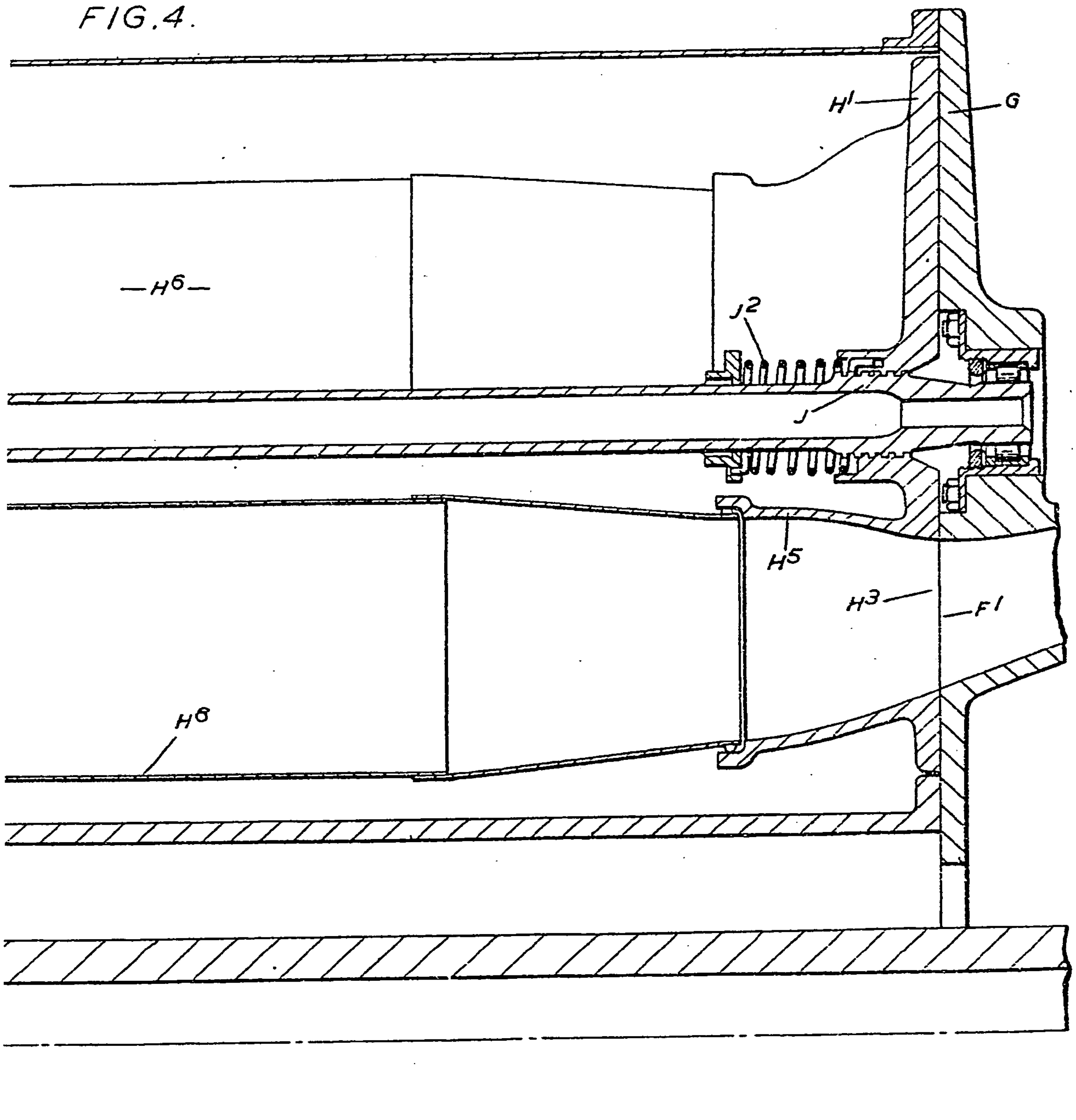


FIG. 4.